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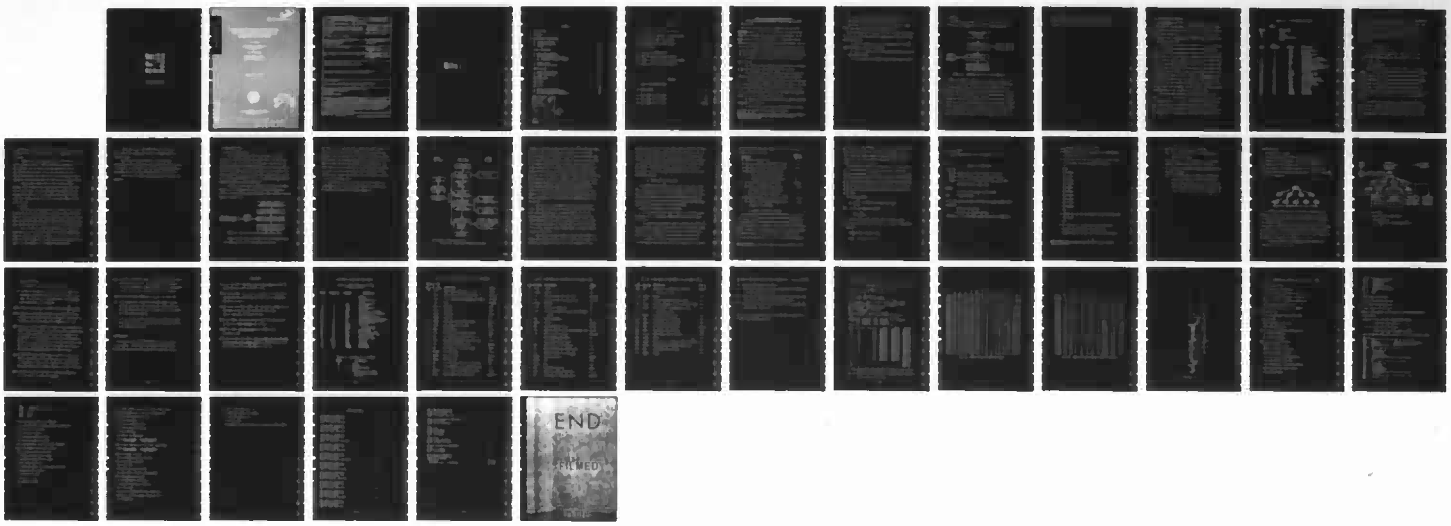

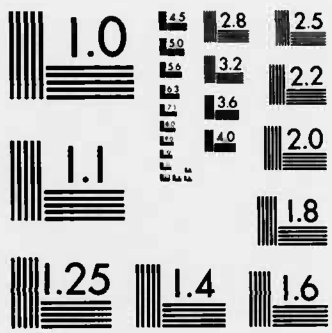

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NRL Memorandum Report 5175

Real-Time Processing System for the NRL Remote Sensing Experiment: Phelps Bank, July, 1982

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A data acquisition and analysis system was implemented to collect multi-channel time-series data at a slow rate (.5 Hz for this implementation) for extended periods (days), quality check the data, and provide real-time output of environmental parameters and data quality assessments. During acquisition and processing, constants, data channels and processing algorithms can be altered by the operator in real time without interrupting data flow and processing. This report describes this system, contains a users guide to the system and gives examples of the outputs.

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CONTENTS

FIGURES

TABLES

REAL-TIME PROCESSING SYSTEM FOR THE NRL REMOTE SENSING EXPERIMENT: PHELPS BANK, JULY, 1982

I. INTRODUCTION

This report describes a software package which was written for USNS HAYES cruise, July 1982. The software is a real-time processing system which interfaces with the data acquisition software*. On the HAYES cruise, 24 channels of Meteorological, Oceanographic, and ship operating parameter data were acquired at a rate of 0.5 Hertz. The real-time processing system facilitated data collection validation, editing, analysis and reporting. The software system operated successfully over two eight day periods to fulfill the intended objectives described below:

1. Perform quality assessment of several data channels and flag noisy data.

2. Convert raw data to physical quantities based on instrument calibrations and physical relationship between the variables.

3. Archive averaged raw data (usually in volts or frequency), calculate physical quantities, and perform data quality assessments.

4. Provide extreme execution flexibility to allow for accurate and reliable measurment of dynamic ocean/atmosphere processes. The flexibility includes capability of on-line alteration of processing algorithms, calibration constants, and choice of instruments without interruption of real-time acquisition and processing.

5. Display in real-time the raw data input, physical quantities, and measure of data quality.

6. Allow ready access to standardized file formats to enable convenient and flexible off-line editing and analysis.

*The data acquisition software was designed and written by Dean Clamons, Ocean Computer Group (Code 5003), Naval Research Laboratory.

Manuscript approved July 20, 1983.

7. Provide generalized processing techniques to permit future use and modification for tasks of a similar general nature.

The software is disc resident on HP-1000 RTE VI system M2 in Code 4310, Naval Research Laboratory, Washington, DC 20375.

After presenting a basic overview of the data collection and processing task, this report will describe the real-time processing system from three perspectives:

1. Part III examines the scientific considerations of environmental instrumentation and data collection.

2. Part IV promotes a user's understanding including instructions for system implementation.

3. Part V explains the technical system software design aspects.

II. OVERVIEW

The fundamental components of the real-time data acquisition and processing during the HAYES 1982 cruise can be shown as Figure 2.1.

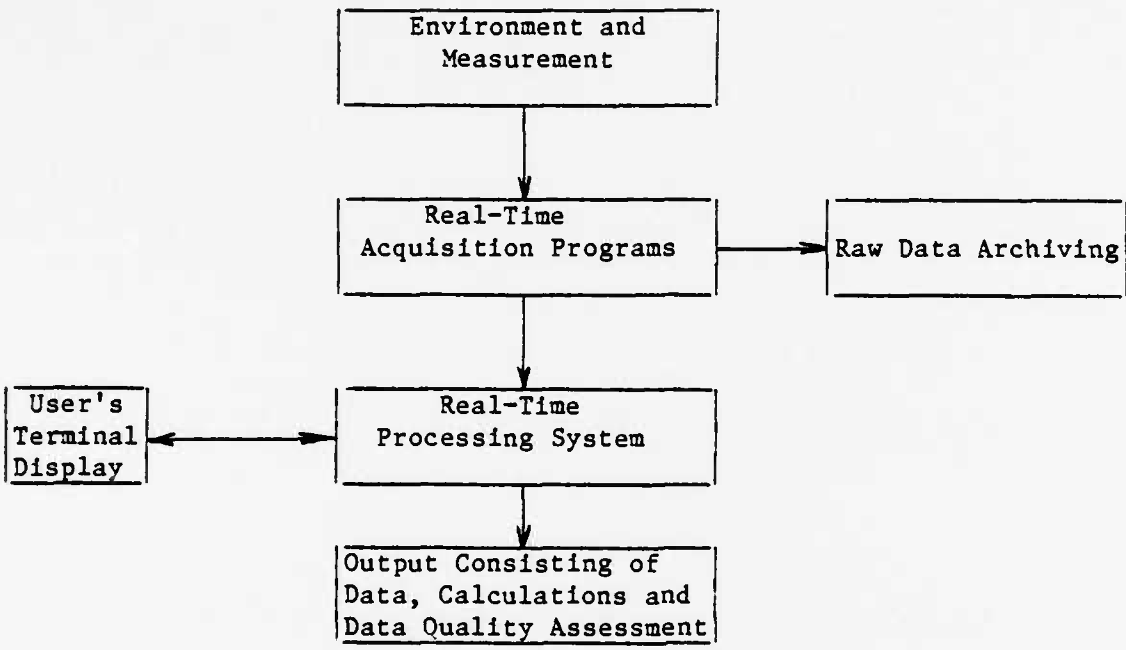


Figure 2.1. Fundamental Processes of Data Collection

Twenty four channels of raw data, read by various instruments both aboard ship and in the surrounding water, are collected by the real-time acquisition program. Next, the data acquisition programs convert the signals to digital form, archive the raw data and pass the time of day and data itself to the processing system. Data processing proceeds according to guidelines established and maintained by the user. Every minute, data averages are output to disk and optionally to the user's display. Every 15 minutes, data averages, results of physical quantity calculations, and data quality assessments are output to both disk and hard copy. The user can examine the output and, if desired, alter the system execution guidelines.

The new guidelines will be reflected in the next processing cycle. The guidelines control instrument selection, conversion factors, fundamental variables, and data quality assessment alarm levels.

III. ENVIRONMENTAL MEASUREMENTS

The USNS HAYES, July 1982 cruise was intended to monitor and examine the Meteorological and Hydrographic environment in shallow water during radar overflights (see Valenzuela and Chen, 1983). The software described in this report was concerned with the time series of meteorological and ship parameter data. A hydrographic data summary appears in Kaiser (1983).

A. Variables Measured

The variables of interest to the experiment were wind speed, wind direction, air temperature, atmospheric dew point (or some measure of humidity), water (bucket) temperature and salinity, latitude and longitude. Table 3.1 lists all the input channels. Wind speed and direction measured relative to the ship must be converted to true values. To do this the ship heading(HD), speed (SPEED), and course (COURSE) are needed. Further, the wind sensors were situated on a mast 22.5 m above the water surface. Ship roll (ROLL) can add a component of motion to the apparent wind velocity, so to correct for this, ship roll must be measured. The USNS HAYES is a two screw variable-pitch-screw ship. The rotation rate (RPM1 and RPM2) and pitch of each screw (PI1 and PI2) was logged. The ship also had a pitot speed log (PLOG) which was logged. The latitude (LAT) and longitude (LONG) were logged directly from a Northstar 7000 Loran-C receiver.

To measure these variables several instrument packages were deployed on the ship. On the starboard bow 10 m above the water line, two air temperature sensors (TA1 and TA2), an atmospheric chilled mirror dew point sensor (TDP1) and a sulfonated polystyrene ion exchange relative humidity sensor (TDP2) were deployed. On the starboard of the aft platform a wind speed (WS1) and wind direction (WD1) sensor was installed. On the

TABLE 3.1. INPUT TO PROCESSING SYSTEM

Time

Words	Description
0	Hours
1	Seconds
2	10's Milliseconds
3	Years

Words	Data Channel #	Channel	Description
0	0	TA1	Air Temperature 1
2	1	TDP1	Dew Point 1
4	2	TA2	Air Temperature 2
6	3	TDP2	Dew Point 2
8	4	WS1	Wind Speed 1, Starboard
10	5	WD1	Wind Direction, Starboard
12	6	WS2	Wind Speed 2, Port
14	7	WD2	Wind Direction 2, Port
16	8	TS	Thermosalinograph Temperature
18	9	CS	Thermosalinograph Salinity
20	10	TW	Water Temperature
22	11	ROLL	Ship Roll
24	12	Spare	For future use
26	13	Spare	For future use
28	14	HD	Ship Heading
30	15	RPM1	RPM, Starboard Screw
32	16	PI1	Pitch, Starboard Screw
34	17	RPM2	RPM, Port Screw
36	18	PI2	Pitch, Port Screw
38	19	PLOG	Pitot Log
40	20	LAT	Latitude
42	21	LONG	Longitude
44	22	SPEED	Ship Speed
46	23	COURSE	Ship Course

port side of the same platform WS2 and WD2 were installed. The water temperature (TS) and salinity (CS) were measured in an instrument well, midships, 7 m below the water line. The roll sensor was on the main deck nearly midships. A towed water sensor (TW) was intermittently deployed from the port fantail. Ship speed and course were calculated and smoothed over about 2 minutes by the Loran-C receiver and then logged.

The specific sensors and their characteristics are described in Kaiser and Munch, (1983).

The sensor outputs are as follows: Digital: TS, CS, PLOG, LAT, LONG, SPEED, COURSE. Frequency: TW. Synchro: HD, PI1, PI2. All the others are voltages.

B. Processing Overview

The raw data was read once every two seconds. This data was averaged over 1 minute to eliminate variance due to ship motion (typically 6-12 sec. period). Then various quantities were calculated from these averages (correlations and variances) and these quantities were averaged over 15 minutes to minimize the variability of the lower atmospheric boundary layer. The appropriate boundary layer averaging interval is actually determined by the properties of the boundary layer existing during the measurement. The appropriate averaging period can vary from 100 to 2000 sec.

Two wind sensors were employed. If the wind was from 0° to 180° relative to the ship, WS1 and WD1 were entered into the data stream and if the relative wind was from 181° to 359° WS2 and WD2 were entered into the processing. Both sensor outputs were recorded in the 2 second data; however, a user option also allowed the selection of only the starboard or only the port wind system data to be entered into the processing stream.

The wind data was corrected for ship roll since the wind sensors were on a high mast. Then the heading was combined with the wind direction. The wind velocity data was combined with the ship velocity data from the Loran-C to give true wind velocity at 22.5 m. This wind velocity was then reduced to 10 m elevation assuming a neutral atmosphere. The TWIND module does the correction to true wind at 22.5 m.

The dew point 2 (TDP2) sensor actually outputs relative humidity. This is converted to a vapor pressure and then to dew point with the use of SPOLY. The water temperature (TW) sensor signal is a frequency which was converted to temperature using the manufacturer's calibration. Details on the calibrations, etc. can be found in Kaiser and Munch, 1983.

C. Output

The original data in digital format was stored so that it could be rerun through the processing module to reproduce or modify any calculations. However, the data acquisition programs did not merge the Loran-C data with the raw data and this produced some downstream processing problems with the 2 sec data set, notably correcting the wind for ship motion.

The raw 2 sec data was wild point edited and then scanned for noise by comparing a running 60 sec variance to an average "background" variance. Any noisy records were flagged, and statistics on noise were compiled for each channel. The user selected the noise threshold for each channel and this threshold could be changed during execution.

The one minute data, which represents atmospheric conditions and not ship motion contamination, is useful to examine variability on short time scales.

The 15 minute output is intended to provide the final characterization of the environment for all the scientists participating in the experiment. This output forms the basis for the Meteorological data summary for the July, 1982 experiment (Kaiser and Munch, 1983).

All of the system output is described further in Chapter IV and Appendix A.

IV. USER'S PERSPECTIVE

A. Basic Software Tasks

The real-time processing software consists of a set of subroutines, an interactive program, and a common block. The "set of subroutines" performs the actual data processing and is controlled by the calling module SAVGS. The program SALTR allows execution characteristics of SAVGS to be altered interactively by enabling the user to control execution parameters and critical constants. The program-to-program communication between the SAVGS modules and the program SALTR is accomplished via SBLK which resides in a system common area.

Software functions can be conceptualized by mapping the software modules onto the Fundamental Data Collection Processes diagrammed in Figure 2.1, thus establishing the correspondence between necessary processes and basic software tasks.

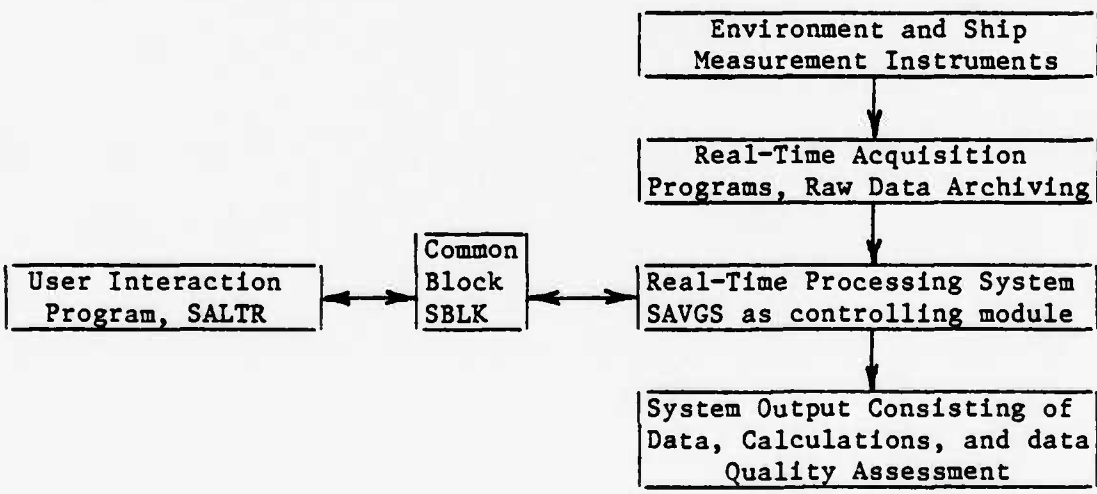


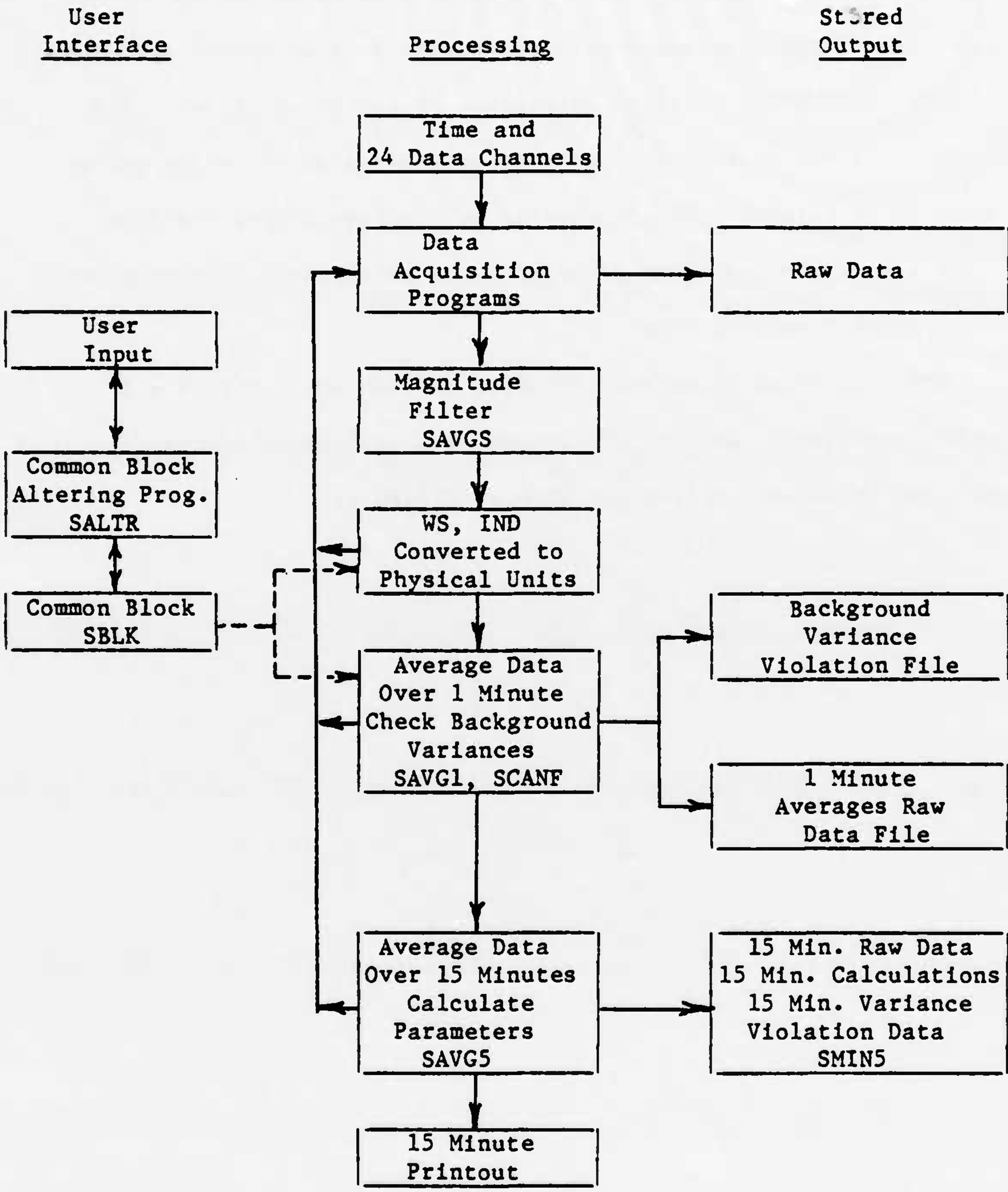
Figure 4.1. Data Collection Processes and Software Tasks

During real-time operation, the data acquisition program invokes a call to SAVGS every DT (2.0 for this application) seconds.

During each call, the data acquisition program passes SAVGS the time and 24 channels of environmental data. SAVGS, acting as the controlling subroutine, calls the remainder of the processing subroutines as needed. During execution, the processing subroutines are in communication with the common block SBLK, which contains guidelines of system execution. The program SALTR is run by the user when any of the system execution guidelines need to be altered. The processing subroutines output the data in various forms. Control then returns to the data acquisition program.

B. Logical Execution Flow

The next level of description from that shown in Figure 4.1 relates basic software tasks to the system flow of logical processing and relationship between software elements, Figure 4.2.



----> Program to Program Communication

Figure 4.2. System Flow of Logical Processing

In Figure 4.2, the data averaging functions, data quality assessment tasks, environmental calculations and output are identified. After having archived the time and 24 channels of 2 second raw data onto magnetic tape, the data acquisition programs pass the time and raw data to the processing set of modules, specifically SAVGS. In SAVGS, the data is scanned for extreme wild points and, if necessary, corrected with a magnitude filter The data is corrected only to the point that ensures continued program execution. Any corrected data is flagged as it passes through the software. Next, a portion of the raw data is converted to physical units, using the System Execution Parameters, to allow for physical unit averaging. These System Execution Parameters, which reside in the common block, SBLK, dictate which algorithms are used to calculate the physical units, the channels to be used in the calculations and the instrument calibrations. These are discussed later in the System Execution Parameters portion of this section.

One minute raw data averages and physical unit averages are formed. The time and 24 channels of raw data are written and filed in SMIN1. Also, using the one minute raw data averages, data quality assessment is implemented by running background variance checks. The running background variance algorithm is outlined later in this section. If the variance calculations show abnormal results, a record containing the time of the "violation" and the channel where the violation occurred is written to file SMINSV.

Fifteen minute raw data averages and physical unit averages are formed. These 15 minute averages are used to derive physical quantities reflecting environmental processes. Data quality assessment is also produced which includes the 15 minute total number of background variances and the cumulative number of variance violations occurring in each data channel. The 15 minute averages, calculated physical quantities, data quality assessment results, and the System Execution Parameters in effect at the end of the 15 minute interval are output to disk into file SMIN5, and hardcopy. The hardcopy 15 minute summary appears in Figure B.1. Descriptions of the disk files are detailed later in this chapter in the System Output section.

1. System Execution Parameters

The System Execution Parameters, which reside in the common block, SBLK, control execution of the real time processing subroutines and are set and altered by use of the interactive program, SALTR. During normal operation all parameters have to be set before SAVGS begins execution. Then, anytime after the real-time processing subroutines begin execution, SALTR can be run interactively to alter the parameters.

Three types of parameters can be controlled:

a. Two flags to indicate whether 2 second or 1 minute averages of raw data should be monitored by dumping data to the user's display screen (CRT).

b. Values called background variance thresholds which govern the level of deviation allowed to be identified in the 19 non-navigation data channels. If the threshold value for a channel is set low, there will probably be greater incidence of threshold variance flags generated.

c. Eight final individual parameters can be viewed in two different classes. The first four control which channels or procedures to use during real-time processing. The second four are actual values involved in processing the data.

Parameter	Choice or Default
1) TA/TDP Use channel 1 or 2?	1 or 2
2) Make roll correction to wind? (0-No, 1-Yes)	0 or 1
3) Make ship correction to wind? (0-No, 1-Yes)	0 or 1
4) Choose WS1 to use for wind calculation?	1
WS2 to use for wind calculation?	2
WS1 and WS2 *for wind calculation?	3
5) PA Atmospheric pressure in millibars	1015.0
6) HT Height of air temperature, dewpoint, and relative humidity sensors above DWL (dead water line) in meters	10.0
7) HW Height of anemometers above DWL in meters	22.5
8) DT Time interval in seconds between cycles or scans of data channels	2.0

2. Background Variance Procedure

A running background variance check was implemented on 20 of the 24 data channels. In the check, a 30-point (60 sec) running background variance was divided by the long term variance for the channel and the ratio is then compared to a threshold. If the threshold is exceeded, the channel is identified as noisy and a record of the violation is written to disk (Refer to Figure A.2 for record format.) The thresholds are initially set by the user and can be altered at any time by using the

*The wind direction dictates which sensor to use as described in III.B.

program SALTR to independently modify each of the data channel thresholds. Total violations for every 15 minutes are recorded on disk and appear on the 15 minute data summary hardcopy (which is essentially the same as Figure B.1). The current background variance and thresholds for each channel also appear on the printout.

The algorithm to perform the variance check was to be executed on each of the 20 channels of data. Thus, in actuality, during each 1 minute variance check, 20 variance ratios are calculated and compared with 20 independent threshold values and if necessary, the running background variance must be updated. For the first one hundred minutes the background variance is assumed to be a simple average of the variance. The algorithm to perform the variance check on only one channel is outlined below.

The running variance

$$V_S = \frac{1}{30} \sum_{i=1}^{30} (X_i - \bar{X})^2, \quad X_i = 2 \text{ second data value.}$$

For $N < 100$, the background variance

$$V_B = \frac{1}{N} \sum_{i=1}^{N} V_S \quad .$$

where N is the number of minutes (sets of 30 data points).

For $N > 100$, V_B is calculated as follows (T is an operator chosen noise threshold):

$$\text{If } \frac{V_S}{V_B} < T, \ V_B = .99\, V_B + .01\, V_S;$$

$$\text{else} \qquad V_B = V_B, \ v = v + 1.$$

C. System Output

Table 4.1 summarizes the output available to the user.

Table 4.1. System Output

Disk Files

SMIN1 - contains time and 1 minute averages of raw data

SMINSV - contains 1 minute data concerning data variance

SMIN5 - contains 15 minute averages of raw data, physical data, calculated data and variance data

Hardcopy

15 minute printout, same content as SMIN5

Tape 2 second raw data

Optional user real-time display (controlled by setting System Execution Parameters):

Time and 2 sec raw data

Time and 1 min averaged raw data

Data formats for disk files SMIN1, SMINSV, SMIN5 appear in Appendix A.

D. Operating the Real-Time Processing System

1. Enable the data acquisition programs.* The major programs are RDSEN, RDN7K, and STN7K.

2. Compile all source codes for the modules listed below, then run the loader using the following instructions:

```
BGRC
RE, %SENSE
RE, %SBLK
RE, %SAVGS
RE, %SFILE
RE, %SRAW
RE, %SAVG1
RE, %SCANF
RE, %SAVG5
RE, %TWIND
RE, %SPOLY
EN
```

3. Compile and then load the parameter alteration program SALTR:

```
RE, %SALTR
EN
```

4. Run SALTR and fill in values for all System Execution Parameters by following the menu instructions.
   Terminate SALTR at any point after entering desired data.

*This is done by interfacing with NRL Code 5003, Shipboard Computer Applications Group

5. Start Data Processing Program ([RU,] SENSE).

   NOTE: Make sure tape drives (LU-8 and 9 usually) and the printer are on line.

   While the system is running, SALTR can be run anytime to change the System Execution Parameter as necessary.

6. To stop data processing process, break the Data Acquisition Program (BR, SENSE).

   NOTE: All file management is automatically performed as long as space remains on specified cartridge in SFILE. Approximately 50 hours of 1 minute data can be stored on one 200 track cartridge. About 50 hours of 2 sec data can be stored on one 10"-800 bpi tape.

V. SYSTEM DESIGN

A. Module Calling Scheme

A top-down modular design approach was implemented in order to facilitate overall task conceptualization, scientific/software functional relationships, and the necessity to fill in software details (such as polynomial instrument calibration equations) as they became available. A hierarchical tree structure having three well-defined levels was envisioned as depicted in Figure 5.1.

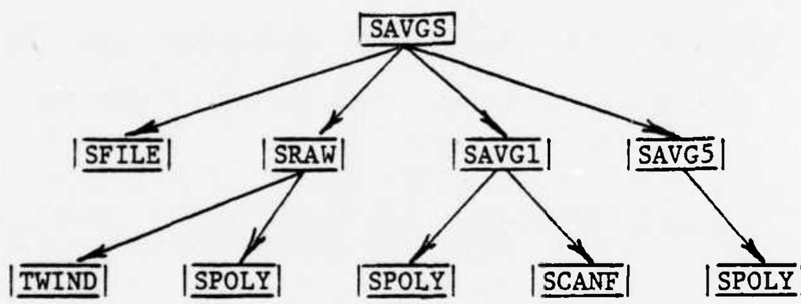


Figure 5.1. Hierarchical Module Calling Scheme

Individual module functions in the module calling scheme are described in the following section. Critical tasks such as process synchronization, dynamic algorithm selection and mathematical calculations involving possibly undefined results were first tested in a bottom-up fashion before integration with the top-down design structure to eliminate the possibility of a real-time operation problem. Finally, before field operation, the entire real-time processing system, as shown in Figure 5.2, was simulated using quality and degenerative test data.

System design began in the beginning of June, 1982 and was completed in July 1982 aboard ship.

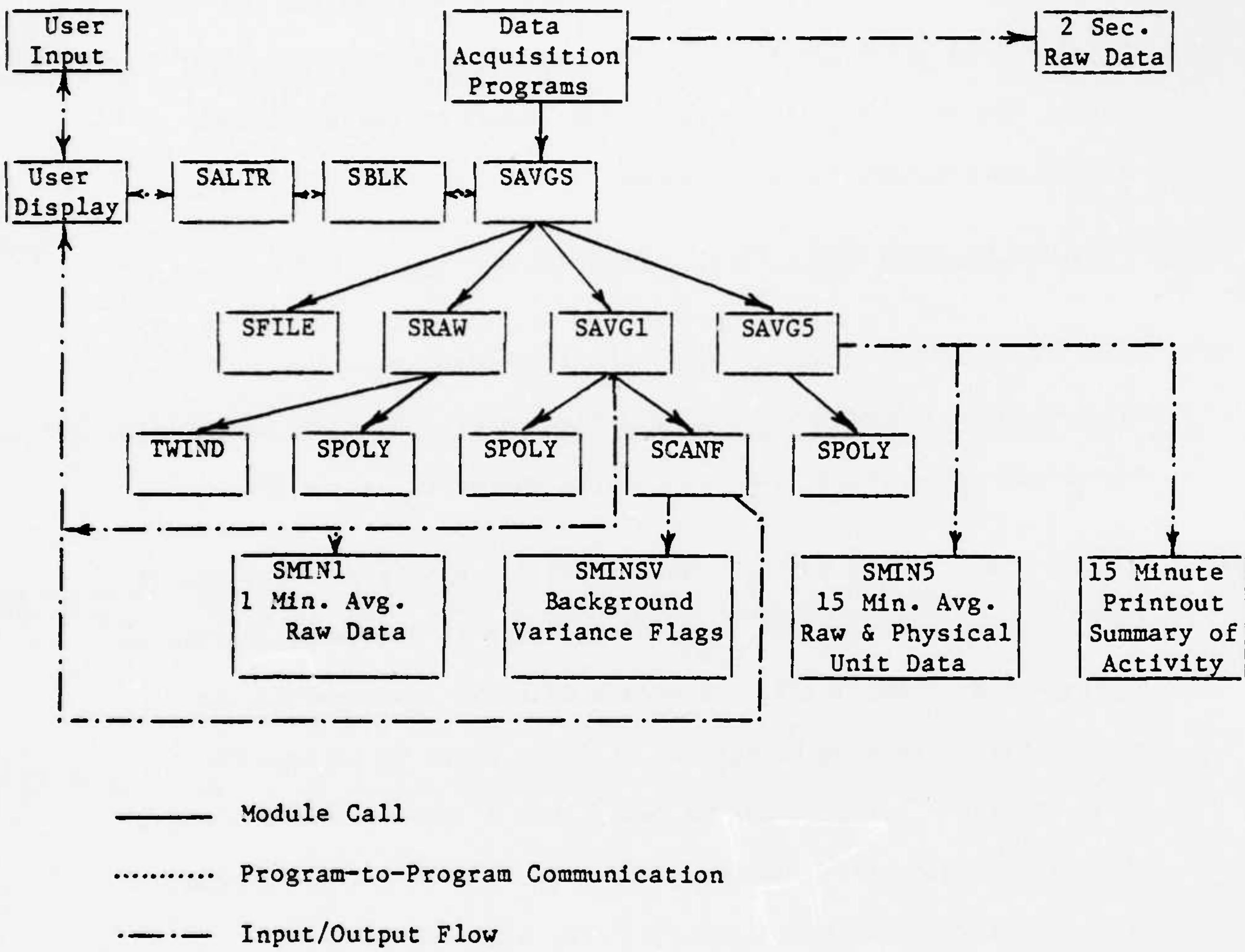


Figure 5.2. Entire System Layout

B. Module Description

The modules used in the system are described below:

SAVGS functions as the main subroutine, or calling subroutine. It also implements a magnitude filter on 19 channels of non-navigation data. The magnitude filter clips data based on preset maximum and minimum values for each channel.

SFILE creates and opens output files SMIN1, SMIN5, and SMINSV on disk.

SRAW operates on raw data using guidelines from the System Execution Parameters (see Section IV.B.1) and acccumulates 2 second data. If requested, using SALTR, raw data can be dumped to user's CRT.

SAVG1 operates on 1 minute averaged data, writes 1 minute averages out to disk, and forms quantities to be used in the 15 minute calculations. If requested, using SALTR, one minute data can be dumped to the user's CRT. A running background variance check is implemented in SAVG1 to catch "noisy" averaged data. One minute variances are calculated for selected channels and if this exceeds the background variance by a predetermined factor, then SCANF is called.

SAVG5 operates on 15 minute averaged data to calculate 15 minute parameters. Results of calculations, data averaging, and background variance data are output to disk. A printout is produced summarizing data collection and analyzed results for the prior 15 minutes.

TWIND calculates the true wind direction. It inputs wind speed and direction, ship speed, course, and heading.

SPOLY calculates the polynomial E(t) and T(e). E(t) is the saturation vapor pressure of air over water in millibars at temperature t. T(e) is the temperature in degrees celsius at which the atmosphere is saturated over water at the vapor pressure e in millibars.

SCANF writes out variance violations to disk and to the user's CRT.

SBLK is the common block. Extensive use of named common is used to facilitate modularity. During original use, SBLK was placed in Reverse Common as the real-time processing system was implemented as a large background program.

SALTR is the interactive program which modifies the common block, SBLK. Ultimately SALTR controls algorithm selection and other parameters in the SAVGS group of modules.

ACKNOWLEDGMENTS

This work was supported by the Naval Research Laboratory basic research program. J. Dean Clamons, Jim Eskensis, and Chuck McMath, NRL Code 5003, designed and implemented the data acquisition system.

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Appendix A. Output Disk File Formats

Table A.1. Data Format for File SMIN1
(1 minute averages)

Words	Channel #	Channel	Description
0			Hours
1			Seconds
2			10's milliseconds
3			Years
4	0	TA1	Air Temperature 1
6	1	TDP1	Dew Point 1
8	2	TA2	Air Temperature 2
10	3	TDP2	Dew Point 2
12	4	WS1	Wind Speed 1, Starboard
14	5	WD1	Wind Direction 1, Starboard
16	6	WS2	Wind Speed 2, Port
18	7	WD2	Wind Direction 2, Port
20	8	TD	Thermosalinograph Temperature
22	9	CS	Thermosalinograph Salinity
24	10	TW	Water Temperature
26	11	ROLL	Ship Roll
28	12	Spare	For future use
30	13	Spare	For future use
32	14	HD	Ship Heading
34	15	RPM1	RPM, Starboard Screw
36	16	PI1	Pitch, Starboard Screw
38	17	RPM2	RPM, Port Screw
40	18	PI2	Pitch, Port Screw
42	19	PLOG	Pitot Log
44	20	LAT	Latitude
46	21	LONG	Longitude
48	22	SPEED	Ship Speed
50	23	COURSE	Ship Course

Table A.2. Data Format for File SMINSV

Words	Description
0	Hours
1	Seconds
2	10's Milliseconds
3	Years
4	Data Channel (0-19) which had a Variance Threshold Violation

Table A.3. Data Format for File SMIN5 (15 minute averages)

Beginning Word

Word	Variable	Description	Units
0	I(1)	Time, hours from beginning of year	Hours
1	I(2)	Time, seconds from beginning of day	Seconds
2	I(3)	10's milliseconds from beginning of second	10 msec
3	I(4)	Year	Integer
4	LAT	Latitude	Deg.
5	RLAT	Latitude	Min.
7	LONG	Longitude	Deg.
8	RLONG	Longitude	Mn.
10	LRSPD	Ship speed calculated by Loran-C	Kts
12	PLOG	Ship speed from Pilot Log	Kts
14	HEAD	Ship heading	Deg.
16	CSE	Ship course calculated by Loran-C	Deg.
18	TA	Air temperature in physical units	°C
20	TDP	Dew point temperature in physical units	°C
22	WS	Wind speed in physical units	m/sec
24	WD	Wind direction in physical units	Deg.
26	BLANK	For future use	----
28	RLSPD	Ship roll speed	m/sec
30	RMSRL	RMS ship roll	Deg.
32	TW	Water temperature from towed thermistor	°C
34	TS	Water temperature from thermosalinograph	°C
36	SALIN	Water salinity from thermosalinograph	°/oo
38	SIGT	Water sigma-T from TS and SALIN	gm/cm^3

Table A.3. Data Format for File SMIN5 (15 min averages) (Cont)

Word	Variable	Description	Units
40	TATW	TA-TW	°C
42	TDPTW	TDP-TW	°C
44	H	Sensible water-to-air heat flux	watts/m^2
46	E	Evaporative water-to-air heat flux	watts/m^2
48	TVATW	TVA-TVW	°C
50	TVA	Virtual air temperature	°C
52	TVW	Virtual air temperature when air is saturated at TW	°C
54	RH	Relative humidity	%
56	QWQA	QW-QA	gm/kgm
58	QW	Specific humidity of air	gm/kgm
60	QA	Specific humidity of air when saturated at TW	gm/kgm
62	TAU	Momentum stress on water	dyne/cm^2
64	L	Monin-Obukhov length scale	m
66	ZO	Sea surface roughness height	cm
68	CD	Drag coefficient for momentum	----
70	CH	Drag coefficient for sensible heat	----
72	CE	Drag coefficient for latent heat	----
74	USTAR	Friction velocity	cm/sec
76	TSTAR	TA	----
78	QSTAR	QA	----
80	PA	Atmospheric pressure	mbar
82	HWO	Height of anemometer above DWL	meters
84	DT	Time interval between data scans	seconds

Table A.3. Data Format for File SMIN5 (15 min averages) (Cont)

Word	Variable	Description	Units
86	HT	Heights of air temperature & dew point sensors above DNL	meters
88	RBLN2	Blank	----
90	VB	Current background variances - array	----
130	RVAL	Current background variance thresholds - array	----
170	FLG15	Total variance flags generated in last 15 minutes - array	----
230	DAT15	15 minute raw data array	----
278	STA	TA variance over 15 minutes	$°C^2$
280	STDP	TDP variance over 15 minutes	$°C^2$
282	SWS	WS variance over 15 minutes	m^2/sec^2
284	SWD	WD variance over 15 minutes	deg^2
286	SPLOG	PLOG variance over 15 minutes	kts^2
288	IBLK2	Blank	----
289	OPTN1	System Execution Parameters algorithm selectors	----
293	RPTN2	System Execution Parameters calibrators	----
301	STS	TS variance over 15 minutes	$°C_2$
303	IBLK5	Blank	----

Appendix B. Available Office Processing Programs to Use with Data Collected

S1R Reads unedited 1 minute data files.

S5R Reads unedited 15-minute data files and echoprints data (Figure B.1) or writes a report (Figure B.2)

S5RP Reads unedited 15-minute data files and writes a report which shows results of the 15-minute calculations (Figure B.3)

SNPLT Plots 2 second raw data, 1 minute raw data, and 15 minute data and calculations. (Figure B.4)

These processing programs are currently on HP-1000 RTE VI system M-2 in Code 4310, Naval Research Laboratory.

```
HAYES   CRUISE   82-16-09          SC=RM

     192/2356
 40 48.68 N       69 17.36 W
LORSPEED = 4.4 kts.  PLOG = 12. kts  HEAD = 106 deg  CSE = 130 deg

--------------- CORRECTIONS TO 10m: ---------------
TA = 14.490 C  TDP = 14.362 C  WS10 =  5.277 MPS  TRUE WD = 101.65

------------- CORRECTIONS FOR SHIP ROLL ----------
ROLL SPEED =  .0 m/s   RMS ROLL =  .6
---------------------------------------------------

TW = 11.60 C   TS = 15.49 C
SAL. = 30.00   SIGT = 22.02 g/cm**3
---------------------------------------------------

TA-TW = 2.886 C   TDP-TW = 2.757 C    eW-e = -.271E+01 mbar
H = -.708E+01 w/m**2                   E = -.346E+02 w/m**2
TVA-TVW = 2.915 C TVA = 14.57 C        TVW = 11.66 C
RH =   99.1602 %  QW-QA = -1.66 g/kg
QW = 8.373 g/kg   QA = 10.03 g/kg
TAU =  .28 d/cm**2   L = 45.6 m
Zo =         .002873 cm
Cd = .92E-03   Ch = .36E-03 Ce = .13E-02
U* = 15.10cm/sec     T* = -.9E-01 C    Q* = .00E+00g/kgm

---------------------------------------------------
SIGMAS: TA = .1208E+00   TDP = .1297E+00   WS = .1415E+02
        WD = .3632E+03   PLOG = .5010E+01
        TS = .0000E+00     CS = .0000E+00
---------------------------------------------------
```

CHAN.	15 FLAG	CUM. FLAG.	BVAR	RVAL	15 DATA
0	0	0.0	.1000E-05	.1000E+04	.1451E+01
1	0	0.0	.1000E-05	.1000E+04	.1473E+01
2	0	0.0	.1000E-05	.1000E+04	.2699E+01
3	0	0.0	.1000E-05	.1000E+04	.4727E+01
4	0	0.0	.1000E-05	.1000E+04	.1379E+00
5	0	0.0	.1000E-05	.1000E+04	.3504E+00
6	0	0.0	.1000E-05	.1000E+04	.1363E+00
7	0	0.0	.1000E-05	.1000E+04	.3859E+00
8	0	0.0	.1000E-05	.1000E+04	.1549E+02
9	0	0.0	.1000E-05	.1000E+04	.3000E+02
10	0	0.0	.1000E-05	.1000E+04	.8221E+04
11	0	0.0	.1000E-05	.1000E+04	-.184E+00
12	0	0.0	.1000E-05	.1000E+04	.1000E+02
13	0	0.0	.1000E-05	.1000E+04	.0000E+00
14	0	0.0	.1000E-05	.1000E+04	.1062E+03
15	0	0.0	.1000E-05	.1000E+04	.1250E+01
16	0	0.0	.1000E-05	.1000E+04	.3027E+02
17	0	0.0	.1000E-05	.1000E+04	.2000E-04
18	0	0.0	.1000E-05	.1000E+04	.6292E+02
19	0	0.0	.1000E-05	.1000E+04	.1266E+02
20					.4081E+02
21					-.693E+02
22					.4422E+01
23					.1301E+03

```
OPTIONS: TA.TDP=1 ROLL COR.WIND=1 SHIP COR.WIND=1 WS1.WS2 OR BOTH=1
         PA = 1013.00   HT =   10.00  HW =   22.50    DT =  2.00
```

Fig. B.1. Sample of the 15-minute data and parameter summary provided on-line during the experiment.

15 MINUTE AVERAGES DATA

DTG.Z	TA degC	TDP degC	TS degC	SAL ppt	SIGT g/cm**3	WS m/sec	WD deg	SHIPS m/sec	CSE deg	HDG deg	LAT deg	LAT mins	LONG deg	LONG mins
189/0406	22.87	22.30	22.293	34 071	23.448	4 5	267	8 1	94	94	37	.69 N	71	26 73 W
189/0437	22.74	22 36	21.002	34.013	23.759	3 2	266	6 9	92	95	37	51 N	71	18 27 W
189/0452	22.60	22.20	20.853	33.898	23.712	3 6	269	6 9	91	95	37	42 N	71	14 09 W
189/0507	22.33	22.13	20 442	33.901	23.824	3 9	260	6.9	91	96	37	39 N	71	9 84 W
189/0522	22.01	21.94	20 246	33.858	23.843	4 3	269	7 0	90	95	37	.38 N	71	5 60 W
189/0537	21.48	21.50	21.277	33.879	23.583	4 1	272	6 9	88	95	37	47 N	71	1 36 W
189/0552	21.43	21 50	22 254	34 055	23.447	3 7	278	6 4	80	95	37	.73 N	70	57.25 W
189/0607	21.86	21.92	24 995	35.587	23.802	4.0	255	6.5	84	96	37	1 14 N	70	53 59 W
189/0622	22.28	22.34	24 147	35 400	23 918	3 6	270	6 6	86	96	37	1 35 N	70	49.53 W
189/0637	22.35	22.38	25.037	35.279	23.557	3 6	275	6.8	86	98	37	1.59 N	70	45 43 W
189/0652	22.78	22.42	26.461	35 839	23.534	4 0	273	6.9	92	104	37	1 65 N	70	41.22 W
189/0707	23.46	22.29	26.848	35.843	23.413	4 3	276	6.8	94	105	37	1 40 N	70	37.04 W
189/0722	23.76	22.10	26.882	35.843	23.402	4 1	280	6.8	93	105	37	1 20 N	70	32.89 W
189/0737	23.84	22.20	27.084	35.844	23.337	4.6	284	6 7	89	105	37	1.19 N	70	29.04 W
189/0752	24.02	22.20	27.765	35.844	23.115	4 8	282	6.6	88	110	37	1.21 N	70	28.26 W
189/0807	24.15	22.11	27 864	35.845	23.083	4 6	279	6 6	88	112	37	1.21 N	70	28 26 W
189/0822	24.23	22.05	27 692	35 844	23.139	4.4	269	6 6	88	115	37	1.21 N	70	28.26 W
189/0837	24.37	22.13	27 543	35.844	23.188	4 7	282	6 7	97	117	37	.87 N	70	14 07 W
189/0852	24.46	22.13	27.482	35.844	23.208	4.5	287	6 8	101	117	37	29 N	70	8.61 W
189/0907	24.51	22.02	27 481	35 831	23.199	4 6	291	6.9	103	117	36	59 58 N	70	4 47 W
189/0922	24.61	22.08	27 448	35 811	23.194	5 4	295	5.0	103	143	36	58 80 N	70	.71 W
189/0937	24.65	22.00	27.415	35 844	23.230	4.9	297	9	33	216	36	58.84 N	69	59.82 W
189/0952	24.63	22.11	27.413	35.752	23.162	4 7	308	9	27	197	36	59.28 N	69	59 54 W
189/1007	24.67	22.04	27.399	35 844	23 235	5.0	304	8	26	221	36	59.64 N	69	59 .32 W
189/1022	24.72	21.96	27.397	35.843	23.235	4.9	300	7	25	220	36	59 99 N	69	59.10 W
189/1037	24.75	21 63	27.396	35.843	23.235	5.2	304	7	23	217	37	.30 N	69	58.94 W
189/1052	24 83	21.62	27.396	35.843	23.236	4.3	302	8	23	202	37	.65 N	69	58.74 W
189/1108	24.92	21.87	27.396	35.843	23.235	3 9	303	8	22	200	37	1 03 N	69	58.54 W
189/1123	24.93	21.66	27.394	35.843	23.236	4.8	300	9	26	202	37	1.44 N	69	58.32 W
189/1138	25.03	21 48	27.385	35.842	23.238	4.3	313	1.0	50	126	37	1.77 N	69	58.03 W
189/1153	24.85	21.26	27.358	35.932	23.315	3.4	289	1 7	194	236	37	2.43 N	69	57 73 W
189/1208	25.19	21.61	27.353	35.994	23.363	3.5	294	.9	69	181	37	2.74 N	69	57 51 W
189/1223	24.92	21.45	27.351	35.995	23 364	4.0	297	.8	28	232	37	2 90 N	69	57 27 W
189/1238	24.96	21.45	27.349	35.994	23 364	4.3	306	9	126	254	37	3.34 N	69	57.04 W
189/1253	25.05	21.43	27.349	35.996	23.366	3 9	294	.8	24	211	37	3.68 N	69	56.94 W
189/1308	25.21	21.67	27 349	35 997	23 366	4.2	296	.8	30	198	37	4.03 N	69	56.72 W
189/1323	25.27	21.77	27 349	35.997	23.366	4.6	298	9	29	201	37	4 41 N	69	56 46 W
189/1338	25.26	21.66	27.348	35.996	23 366	4 3	290	9	31	202	37	4.78 N	69	56 19 W
189/1353	25 28	21.82	27 348	35.994	23.365	4.4	282	9	23	194	37	5.17 N	69	55.95 W
189/1408	25.30	21.73	27 346	35 991	23.363	4 5	284	8	27	178	37	5 56 N	69	55 71 W
189/1423	25.24	21.69	27 344	35.986	23.360	4 4	285	.9	29	194	37	5.93 N	69	55 44 W
189/1438	25.28	21.86	27 346	35.987	23.360	4.9	299	1.1	102	231	37	6.32 N	69	55.25 W
189/1738	25 47	20 48	27 359	35.966	23.340	3.4	254	1.1	38	152	37	32 24 N	69	59.20 W
189/1753	25.42	20 57	27 350	35.963	23.341	3.2	245	1.2	25	154	37	32.74 N	69	58.85 W
189/1808	25 76	20.14	27 331	35.966	23 349	2.9	246	1.3	41	116	37	33.23 N	69	58 38 W
189/1823	26 00	19 94	27 355	35.970	23 344	2 7	241	1 2	31	125	37	33 73 N	69	57.99 W
189/1838	25.09	20 23	27.391	35.969	23.332	2.4	240	1 2	166	275	37	34 21 N	69	57 82 W
189/1853	25.06	19.98	27 401	35 998	23.351	3.8	302	2 5	98	207	37	34 79 N	69	57 98 W

Fig. B.2. Sample 15-minute average data output.

15 MINUTE AVERAGES PARAMETERS

DTG Z	TA-TW degC	TVA-TVW degC	RH %	TAU g/cm**2	CD x10-3	U* cm/sec	L m	Z0 cm	H W/m**2	E W/m**2
189/0406	58	59	96	210	89	13 35	-29 3	2244E-02	7 567	- 082
189/0437	1 74	2 00	98	095	81	8 99	-16 8	1018E-02	4 031	-15 883
189/0452	1 75	2 00	98	131	84	10 55	-36 9	1401E-02	2 965	-17 959
189/0507	1 68	2 20	99	158	86	11 54	-86 9	1678E-02	1 668	-24 116
189/0522	1 77	2 07	**	195	88	12 83	-138 6	2074E-02	1 422	-26 265
189/0537	20	24	**	175	87	12 15	-17 1	1859E-02	9 791	-5 351
189/0552	- 83	- 97	**	138	84	10 78	-8 0	1463E-02	14 578	10 473
189/0607	-3 13	-3 77	**	161	86	11 64	-5 7	1708E-02	36 044	49 736
189/0622	-1.86	-2 23	**	132	.84	10 55	-5 7	1401E-02	19 069	26 456
189/0637	-2.69	-3 25	**	125	.83	10 28	-4 5	.1332E-02	22 476	38 960
189/0652	-3.69	-4 57	98	163	.86	11 74	-5 2	.1737E-02	28 776	69 024
189/0707	-3 38	-4 38	93	191	88	12 73	-6 8	2041E-02	28 432	84 007
189/0722	-3.12	-4 16	90	167	87	11 91	-6 0	1788E-02	26 136	87 801
189/0737	-3.25	-4 32	90	221	90	13 69	-8 3	2362E-02	28 799	96 206
189/0752	-3 74	-4 99	89	244	91	14 39	-8 6	2610E-02	32.458	116 357
189/0807	-3 72	-5 00	88	229	90	13 97	-8 0	2460E-02	31.739	117 298
189/0822	-3.46	-4 71	87	203	.89	13 14	-7 2	2175E-02	29 261	108 371
189/0837	-3.17	-4.37	87	.234	91	14 11	-9 1	.2509E-02	28.787	110 282
189/0852	-3.02	-4 20	87	216	90	13 56	-8 5	2315E-02	27 329	105 095
189/0907	-2.97	-4 17	86	229	90	13 97	-9 3	2460E-02	27.467	109 864
189/0922	-2.84	-4.02	85	327	95	16 68	-14 8	3506E-02	29.335	125 560
189/0937	-2.77	-3 95	85	.261	.92	14.92	-11 4	.2805E-02	27.229	114 960
189/0952	-2.78	-3.95	86	.238	.91	14 25	-10 1	.2559E-02	26 680	108 434
189/1007	-2 73	-3.91	85	.276	.93	15 35	-12 3	.2968E-02	27 418	116.526
189/1022	-2.67	-3 86	84	.255	.92	14.75	-11 3	.2739E-02	26 501	114 009
189/1037	-2.65	-3.90	82	296	.94	15 89	-13 7	.3179E-02	27.389	127 840
189/1052	-2 57	-3 81	82	.194	88	12 87	-8 2	.2085E-02	24 174	106.790
189/1108	-2 48	-3.68	83	.153	86	11.41	-6 2	.1640E-02	22 418	92.454
189/1123	-2.46	-3.70	82	.244	.91	14 43	-11 2	2623E-02	24 984	117 003
189/1138	-2.36	-3.62	80	.190	88	12 73	-8 4	.2041E-02	22 942	107 632
189/1153	-2.51	-3.81	80	.111	.82	9 73	-4 1	.1192E-02	21 031	87 376
189/1208	-2.16	-3.39	80	.122	.83	10.22	-5 0	.1315E-02	19 946	86 512
189/1223	-2.43	-3.69	81	.163	.86	11.78	-6 8	.1747E-02	22.505	100 380
189/1238	-2.39	-3.65	80	.190	88	12.73	-8 3	.2041E-02	23.129	107 333
189/1253	-2.30	-3 57	80	.151	.85	11.34	-6 3	.1620E-02	21.507	97 328
189/1308	-2.14	-3 36	80	.179	.87	12.35	-8.2	.1922E-02	21 513	101 232
189/1323	-2.08	-3.28	81	229	90	13.97	-11 4	.2460E-02	22.405	110 762
189/1338	-2.08	-3 31	80	.187	88	12.63	-8 8	.2008E-02	21 429	103 269
189/1353	-2.06	-3.26	81	.204	.89	13 21	-9 9	.2198E-02	21.756	104 668
189/1408	-2.05	-3.26	80	210	.89	13.38	-10 3	2256E-02	21.804	107 293
189/1423	-2 10	-3 32	80	205	89	13 24	-9 9	.2210E-02	21.973	107 013
189/1438	-2.07	-3.25	81	.260	.92	14.89	-13.4	.2792E-02	22.984	115 258
189/1738	-1.89	-3.32	73	112	.82	9 79	-4 7	1208E-02	18.476	97 020
189/1753	-1.93	-3.35	74	.097	.81	9.12	-3 9	1047E-02	18 170	90 012
189/1808	-1.57	-3 05	71	077	79	8.13	-3 1	.8334E-03	16 169	85 188
189/1823	-1.36	-2.87	69	.064	78	7 39	-2 5	6873E-03	15 005	80 114
189/1838	-2.30	-3.78	74	.051	.76	6 59	-1 5	5473E-03	17 355	70 531
189/1853	-2.34	-3 86	73	148	.85	11.24	-6 1	1592E-02	21 613	117 045

Fig. B.3. Sample 15-minute parameter calculation output.

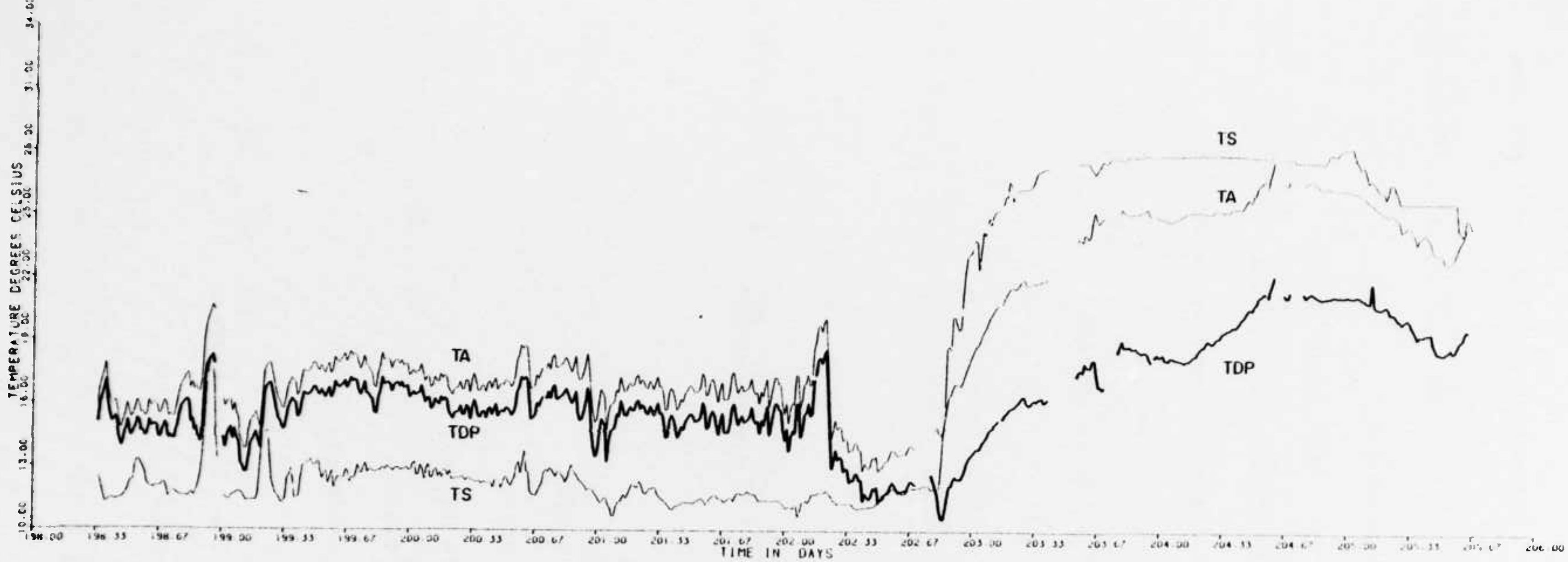

Fig. B.4. Sample plot of data and parameter calculation.

Appendix C. Scientific Modules and Algorithms

Roll correction to wind:

HW = height of wind sensor in m

DT = time interval between data scans in sec

ROLL = roll sensor in degrees - current scan

ROLLL = roll sensor in degrees - previous scan

WS = measured wind speed in m/sec

WD = measured wind direction in degrees

Roll velocity, VR:

VR = 1.943*HW*(ROLL - ROLLL)/(DT*57.926)

Across ship, WX:

WMX = WS*SIN(WD/57.296) - VR

WMY = WS*COS(WD/57.926)

Roll corrected wind speed WS' & direction WD'

WS' = $[WMX^2 + WMY^2]^{1/2}$

WD' = arctan (WMY/WMX)

Ship motion correction to wind:

SPEED = ship speed in kts

COURSE = ship course in degrees

HDG = ship heading in degrees

DIR = wind direction in degrees (WD')

SPD = wind speed in knots (WS')

TWD = corrected wind direction in degrees

TWS = corrected wind speed in knots

Use subroutine TWIND.

```
FTN,L
      SUBROUTINE TWIND(SPEED,COURSE,HDG,DIR,SPD,TWD,TWS)
      D=(HDG+DIR)*3.14159/180.0
      C=COURSE*3.14159/180.0
      SVX=SPEED*COS(C)
      SVY=SPEED*SIN(C)
      TWX=SPD*COS(D)-SVX
      TWY=SPD*SIN(D)-SVY
      TWS=SQRT(TWX*TWX+TWY*TWY)
      TWD=ATAN2(TWY,TWX)*180.0/3.14159
      IF(TWD.LT.0.0)TWD=TWD+360.0
      RETURN
      END
      END$
```

To correct wind to 10 m level:

WS_{10} = 10 m corrected wind speed

HW = height of wind sensor is m

$$WS_{10} = WS/[1 + .076 \ln(HW/10)]$$

Saturation vapor pressure from dew point or dew point from saturation vapor pressure:

IPOLY = 1: RIN = Saturation vapor pressure in mbar

ROUT = Dew point in deg C

IPOLY = 2: RIN = Dew point in deg C

ROUT = Saturation vapor pressure in mbar

The polynomials in SPOLY were obtained by fitting data from List (1966).

```
FTN7X,L
      SUBROUTINE SPOLY(DIN,DOUT,IPOLY),1982 Cruise E(t) and T(e)
C     *
      REAL*8 DIN                    !  Double precision input to subroutine
      REAL*8 DOUT                   !  Double precision output from subroutine
      INTEGER IPOLY                 !  Operational mode of subroutine
      REAL*8 D0,D1,D2,D3,D4,D5      !  Coefficients
C     *
C     *  E(t)   Saturation vapor pressure from dew point
C     *
      IF (IPOLY.EQ.1) THEN
        D0=6.1183482D0
        D1=0.42750748D0
        D2=0.0169417D0
        D3=0.00011912806D0
        D4=0.0000061844 3D0
        DOUT=D0+(D1*DIN)+(D2*DIN*DIN)+(D3*DIN**3)+(D4*DIN**4)
      END IF
C     *
C     *  T(e)  Dew point from saturation vapor pressure
C     *
      IF (IPOLY.EQ.2) THEN
        D0=-12.304D0
        D1=2.42893D0
        D2=-0.0626510D0
        D3=0.0009367922D0
        D4=-0.0000068904 1D0
        D5=1.93622D-8
        DOUT=D0+(D1*DIN)+(D2*DIN**2)+(D3*DIN**3)+(D4*DIN**4)+
     2    (D5*DIN**5)
C       *
C       *  To correct for bad fit of T(e) polynomial to table
C       *
        IF (DOUT.LT.16.0) THEN
```

```
            DOUT=0.86+0.95*DOUT
          ELSE
            DOUT=DOUT+0.01*(DOUT-22.0)**2-0.31
          END IF
C           *
        END  IF
C       *
        RETURN
        END
```

To calculate relative humidity from dewpoint:

E(T) = saturation vapor pressure in mbar at temperature T

TA = air temperature in deg C

TDP = dew point in deg C

PA = atmospheric pressure in mbar

RH = relative humidity in percent

RH = 100*E(TDP)*(PA - E(TA))/(E(TA)*(PA - E(TDP)))

To calculate dewpoint from relative humidity:

RH = relativity humidity in percent

R = mixing ratio over water in gm/gm

R = (RH/100)*.62197*E(TA)/(PA - E(TA))

E(TDP) = R*PA/(.62197 + R)

Use SPOLY with IPOLY = 1 to obtain E(TA) and E(TDP).

To calculate sea water sigma-T:

T = temperature in deg C

S = salinity in $^{o}/_{oo}$

σ_T = sigma-T in gm/cm^3

$\sigma_T = 29.42 - .270T - .0042(T-21)^2 + (.7954 - .00162T)*(S-34)$

This is a quadratic fit to the data in Stommel, 1965.

To calculate Meteorological variables:

CD = drag coefficient

$CD = (0.61 + 0.63*WS_{10})/1000.$

U* = friction velocity in cm/sec

$U* = 100 \sqrt{CD}* WS_{10}$

TVA = virtual air temperature

$$TVA = \frac{TA(1 + E(TDP))}{(PA - E(TDP))} \quad \frac{(1 + .62197\ E(TDP))}{(PA - E(TDP))}$$

TVW = virtual temperature of air at water temperature

$$TVW = \frac{TA\ (1 + E(TW))}{(PA - E(TW))} \quad \frac{(1 + .62197\ E(TW))}{(PA - E(TW))}$$

RHO = air density in gm/cm^3

RHO = .34838*PA/(1000*(TVA + 273.16))

TAU = wind stress in $dyne/cm^2$

$TAU = RHO*(U*)^2$

H = sensible heat flux in $watt/m^2$

$H = 1046.4*(8.7 + .99*(TW - TA)*WS_{10})*RHO$

CH = drag coefficient for heat

CH = H/((RHO*WS(TA - TW)*1046.4)

E = evaporative heat flux in $watt/m^2$

$CE = 1.32 \times 10^{-3}$

$E = 1.515 \times 10^9*RHO*CE*WS*(E(TW) - E(TDP))/PA$

Q = specific humidity in g/Kg at temperature T°C

Q = .621*E(T)/PA

L = Obukov length scale in m

$L = -.267*(TA + 273.16)*(U*)^3*RHO/H$

Z_o = roughness height in cm

$Z_o = (U*)^2/79,380$

The parameterizations of CD, CE, CH, E, H are due to Smith (1980).

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